Virtual National Laboratory for Heavy Ion Fusion

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HIF News

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Solenoidal field influences beam neutralization

An analytical electron fluid model has been developed to describe the plasma response to a propagating ion beam. The model predicts very good charge neutralization during quasi-steady-state propagation, provided the beam pulse duration is much longer than the electron plasma period. In the opposite limit, the beam pulse excites large-amplitude plasma waves. Figure 1 shows the influence of a solenoidal magnetic field on charge and current neutralization. Analytical studies show that the solenoidal magnetic field begins to influence the radial electron motion when $\omega_{ce} > \beta\omega_{pe}$. Here, ω_{ce} is the electron gyrofrequency, ω_{pe} is the electron plasma frequency, and $\beta = v_b/c$ is the ion beam velocity. If a solenoidal magnetic field is not applied, plasma waves do not propagate. In contrast, in the presence of a solenoidal magnetic field, whistler waves propagate ahead of the beam and can perturb the plasma ahead of the beam pulse. In the limit $\omega_{ce} >> \beta\omega_{pe}$, the electron current completely neutralizes the ion beam current and the beam self magnetic field greatly diminishes. Application of an external solenoidal magnetic field clearly makes the collective processes of ion beam-plasma interactions rich in physics content. Many results of the PIC simulations remain to be explained by analytical theory. Four new papers have been published or submitted describing plasma neutralization of an intense ion beam pulse. Key references for this work can be found as 2004 PPPL reports at website http://www.pppl.gov/pub_report?/

– Igor Kaganovich

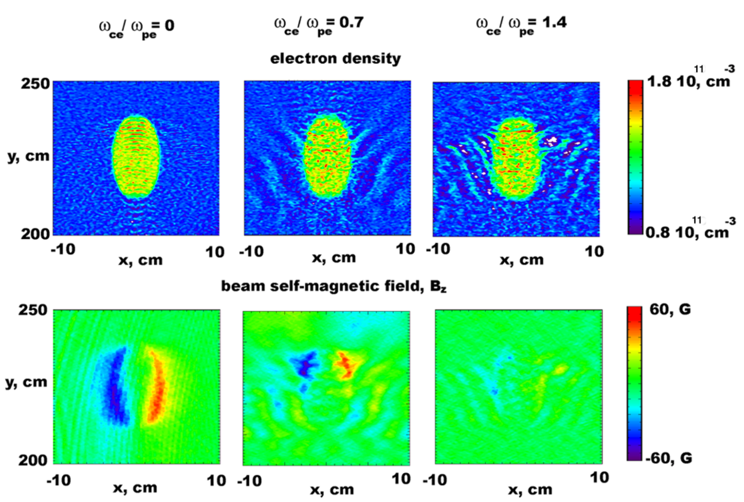

Figure 1. The charge and current neutralization of the ion beam pulse is calculated in two-dimensional slab geometry using the LSP code for various magnetic field strengths corresponding to ω_{ce}/ω_{pe}= 0, 0.7, 1.4. Shown in the figure are electron charge density (top) and beam self magnetic field (bottom) contour plots in (x,y) space. The background plasma density is $n_p=10^{11}$cm^{-3}. The beam velocity is v_b=0.2c, the beam current 48.0A corresponds to the ion beam density $n_b=0.5n_p$, and the ion beam charge state is equal to unity. The beam dimensions (r_b=2.85cm and τ_b=4.75 ns) correspond to a beam radius $r_b=1.5c/\omega_{pe}$, and pulse duration $\tau_b\omega_{pe}$=75. The solenoidal magnetic field 1014 G corresponds to $\omega_{ce}=\omega_{pe}$.

A non-destructive ion-beam charge distribution diagnostic

An e-beam diagnostic system for measuring the charge distribution of an ion beam without changing its properties is developed for HIF beam physics studies. Conventional diagnostics require temporary insertion of sensors into the beam, but these stop the beam or alter its properties. In this new diagnostic a low-energy, low-current electron beam is moved transversely across the ion beam; the charge density profile of the ion beam is determined from the e-beam deflection. The e-beam is translated by dipole magnets in a chicane setup allowing the electron beam to traverse the ion beam at various positions from the beam axis. The background magnetic field (~0.5 G), which affects the trajectory of the low energy e-beam, is cancelled by a Helmholtz coil. The image of the e-beam spot on a YAP scintillator (18 photons/keV, 27 ns decay constant) is monitored using a gated-camera, then processed with image analysis software (Image-J). Figure 1 shows theoretical, experimental and overall performance of the e-beam diagnostic to measure an ion beam.

– P. K. Roy, E. Henestroza, S. Eylon, F. Bieniosek, M. Amezcua, W. Greenway, and S.S. Yu

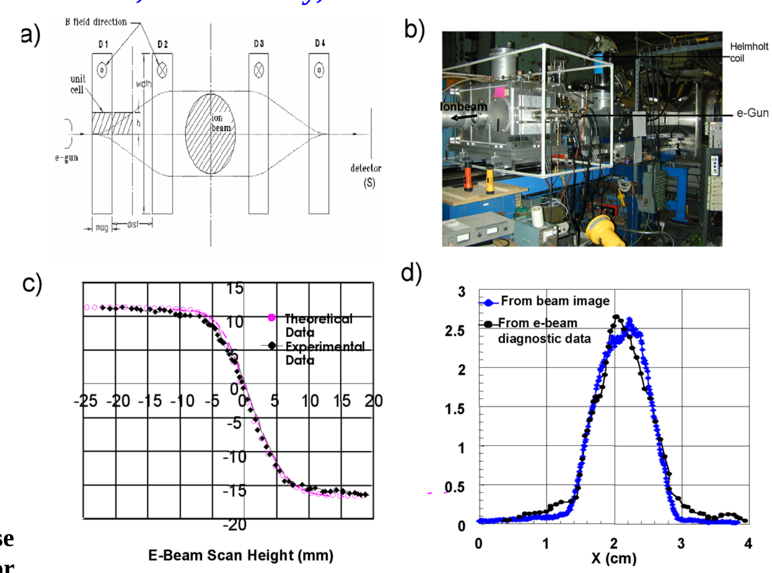

FIG.1: (a) A sketch of the e-beam diagnostic system, (b) e-beam diagnostic system in the NTX beamline, (c) theoretical and experimental data of the e-beam (8 keV, 1 A) deflection by the ion beam (264 keV, 25 mA, K^+), (d) the ion beam density profiles measured destructively (scintillator based image) and non-destructively with the e-beam diagnostic system. The integrated density profile by the e-beam diagnostic was obtained using a least square fit to calculate the derivative of the experimental deflection data.

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